E.I. DU PONT DE NEMOURS AND COMPANY

Thallium/Lead Thin Films for Advanced Superconducting Electronic Devices

Superconductivity holds great promise for reducing energy consumption in practically any process that uses or transports electricity. Radar components, power transmission lines, communications satellites, and a host of electronic and electrical devices, for example, are good candidates for superconductor applications.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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New Technology for Making Superconducting Components

At the time of its proposal to the ATP, DuPont had carried out a three-year research program to develop high-temperature superconducting (HTS) materials and was debating whether to disband the effort because of its high technical uncertainty. The properties of HTS materials were still not well understood, fabrication processes had not been developed, and the technical and commercial viability of the materials had not been proven. DuPont said later that continuation of its HTS research hinged on receiving an ATP award, which the company considered an indicator of the promising nature of the work.

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With its ATP award, DuPont developed thin-film HTS fabrication technology. It is generic enough to use with a variety of HTS materials that have form, structure, and performance properties similar to those of thallium/lead. The technology is particularly useful when using thallium/barium or thallium/lead in the fabrication of HTS electronics components. The company developed two thin-film fabrication processes — a two-step approach using sputtering and post-annealing and a single-step approach with simultaneous sputtering and annealing. Photolithographic and ion-milling techniques are used to form circuits and other electronic features in the films. The viability of the two processes was demonstrated by constructing and testing several basic electronic components, including oscillators, filters, mixers and coplanar-designed transmission lines.

. . . HTS component technology recognized as one of the "Top Products of 1993" by Microwaves & RF magazine . . .

Many New and Potential HTS Products

DuPont has developed six electronic-component products: thin films of two or three inches in diameter made on HTS substrates of erbium/barium, thallium/barium, or thallium/lead. All six of these products use the new HTS thin-film fabrication technology developed in the ATP-funded project. In addition, the company usually fabricates electronic components, on the thin-film wafers, cuts the wafers into discrete components, and encases them in metal casings, all according to customer specifications.

The company has begun substantial marketing efforts and is successfully selling products. Most of these are made with erbium/barium and thallium/barium rather than thallium/lead. Applications requiring the higher operating-temperature capabilities of thallium/lead HTS components have not yet developed significantly, due in part to improved cryogenics technology that has increased the number of application areas where the two other HTS materials are useful.

DuPont has maintained its long-term vision and

PROJECT HIGHLIGHTS

produce high-temperature superconducting (HTS) electronics components at reasonable cost.

Duration: 4/1/1991 — 3/31/1994
ATP Number: 90-01-0064

Funding (in thousands):

ATP	$1,590	67%
Company	784	33%
Total	$2,374	

Accomplishments:
DuPont accomplished the R&D goal and has demonstrated several component products that directly use the new technology. It has also marketed products based in part on procedures developed by the project, but using thallium/ barium as a key ingredient instead of thallium/ lead. Indicators of successful development of the technology are that the company:

- published more than 20 research papers on the technology in professional journals;

- had its HTS component technology recognized as one of the "Top Products of 1993" by Microwaves & RF magazine in December 1993;

- introduced HTS thin-film products that, when built into larger systems such as magnetic resonance imaging machines and communications satellites, can lead to higher performance at lower overall cost;

- and worked with a small equipment-supplier company to develop improved HTS thin-film fabrication equipment.

Commercialization Status:
The market for new products based on the fabrication technology developed in the project is well established, even though applications that use thallium/lead as the HTS material have been slow to develop. Several products made with the new HTS technology are being marketed. The company has invested large sums to scale up for production in anticipation of increased demand in the near future.

Outlook:
Use of the new process technology can substantially reduce the cost and improve the quality of superconductors in many applications. Applications based on this technology could, for example, make magnetic resonance imaging and terrestrial and satellite communications less expensive and more efficient to operate, generating widespread benefits valued at tens of millions of dollars.

Composite Performance Score: * * *

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continues to develop HTS electronics components based on erbium/barium, thallium/barium and thallium/lead. The payoffs may be coming soon, especially in magnetic resonance imaging (MRI) equipment and possibly in terrestrial and satellite communications. HTS materials also have potential use in nuclear magnetic resonance instruments, superconducting quantum interference devices, and a variety of microwave applications.
For superconductor technology to realize its full potential, however, more advances have to be made in the technology. DuPont continues to fund its HTS research program at significant levels.

Less-Costly, More-Efficient Electronic Equipment

HTS processes developed in the ATP project could make superconductivity-based equipment less costly and more efficient to operate. HTS-based signal coils, for example, permit the use of a low-cost permanent magnet for MRI, an arrangement that could reduce the installation cost of this MRI machine to as little as one-tenth that of a standard MRI device. In addition, the use of HTS electronics enables equivalent or better MRI performance at much lower cost. IGC, an MRI manufacturer that uses DuPont HTS electronics in its products, reports that operating costs for its MRI machines are expected to be about one-sixth those for currently available competitor machines that use low-temperature superconducting technology. Thus, the new technology helps reduce MRI capital and operating costs while improving diagnostic effectiveness.

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The benefits of the new HTS technology are likely to be substantial and widespread. In MRI and satellite communications, for example, the chain of events leading from the manufacturer of the components to the end users has many steps. At each step, some benefits from the technology are likely to accrue to intermediate customers and end-users, who pay for only a small part of the value they receive from the technological advance. Given the large number of end users for MRI and satellite services, the aggregate value of those spillover benefits is likely to be in the tens of millions of dollars.

. . . a small equipment supplier, the Kurt J. Lesker Company . . . improved fabrication equipment . . .

During this project, DuPont worked with a small equipment supplier, the Kurt J. Lesker Company, to develop improved fabrication equipment for depositing HTS material on a wafer. Lesker is now making these improved machines available to other companies, as well as to DuPont.